Evaluating The Risks Of Importation of Exotic Pests Using Geospatial Analysis and a Pest Risk Assessment Model [1]

Sue D. Cohen
U.S. Department of Agriculture
Animal and Plant Health Inspection Service
Riverdale, Maryland U. S. A.

ABSTRACT

The volume of agricultural imports into the United States has increased over the years. Now, U.S. Agricultural imports are more diversified and come from a greater number of geographic locations. To keep up with the changes, additional tools such as geographic information systems, geospatial analysis and risk modeling are needed for pest risk assessment. A pest risk assessment model was developed to evaluate the threat of importation of exotic pest species. The potential risks of importing an exotic species may be rated as high, medium, low for each of the individual elements in the model. The individual element ratings can be combined for the cumulative risk rating. This model is extremely flexible as it accepts both qualitative and quantitative data, and the integration of goespatial applications and analysis. Geospatial applications, such as proximity, buffer, and network analysis, are illustrated using data from an actual introduction of an exotic disease, *Melampsora larici-populina* (Eurasian Poplar Leaf Rust) into the United States.

1.0 Introduction

Movement of non-indigenous organisms (exotic Pests) into the United States is a greater concern now that imports have increased, diversified, and come from w wider range of geographic locations. A recent report from the Office of Technology Assessment (OTA) examined issues dealing with harmful non-indigenous species in the U.S. And estimated that 239 plant pathogens in the U.S. Today originated from outside the United States (OTA, 1993). Economic losses associated with the introduction of exotic pests into the U.S. can be high. For example, the Office of Technology Assessment estimated a cumulative economic loss of $26,924,000 based on a worst case scenario of the introduction of three plant pathogens; annosus root disease, larch canker, and soybean rust fungus (OTA, 1993). Also, increased trade has contributed to the introduction of exotic organisms through new pathways assisted by man (OTA, 1993).

The evaluation of risks associated with new pathways and change in imports requires improved risk assessment procedures. One approach is to develop a model or framework in which descriptive and numerical information can be included in the assessment (Orr *et al*., 1993; Cohen *et al*., 1995). This pest risk assessment model is based on the idea that risk is equal to the probability of pest establishment and the consequences of pest establishment. Probability of pest establishment includes: the elements of association of pest with host at origin; the potential for entry of the pest into the U.S.; the potential for colonization; and the potential for spreading of the pest within the U.S. The consequences of pest

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establishment include: the economic damage potential of the pest; the environmental damage potential caused by the pest; and the perceived damage or social and political influence associated with the exotic pest issue. Information can be collected for all the elements of the risk probability formula and based on the information collected, individual elements are rated as high, medium or low. A combined rating for all elements can be either high, medium or low risk.

Geospatial analysis provides an ideal companion to the pest risk assessment model. Traditionally, this analysis studies locational, temporal and emerging patters trends. These trends may include predictions of geographic areas of risk to biological invasion and the potential risk of establishment of an exotic organism. For this situation, geospatial analysis is a beneficial tool as it accepts descriptive and numerical data and may be rapidly completed with commercially available GIS software on desktop computers (Cohen, 1994).

The purpose of this study was to develop GIS applications for geospatial analysis consistent with the pest risk assessment model (orr et al., 1993) using data from a recent exotic pest introduction Eurasian Poplar Leaf Rust (*Melampsora laurici-populina*), into the United States (Newcombe and Chastagner, 1993; Newcombe *et al*, 1994). This rust disease was selected because it offers a degree of complexity for risk assessment y way of : 1) an alternate life cycle with multiple hosts; 2) overwintering reproductive spores; 3) spread by wind of asexual spores; and 4) germination of asexual spores affected by environmental factors.

2.0 METHODS AND MATERIALS

Geospatial analysis was conducted using a Gateway 2000 P5-150 MHz with 24 MB RAM personal computer running desktop mapping software, Maptitude (Caliper Corporation) version 4.0 or Atlas-GIS for windows (ESRI Corporation) version 2.0, running under Windows 95. Background map data was derived from the United States Census Bureau’s Tiger Files.

Disease incidence data for the Eurasian Poplar Leaf Rust example is from studies by Newcombe and Chastagner (1993), Newcombe et al. (1994), and Chastagner (personal communication). Temperature and relative humidity data is from studies by Spiers (1978) and Chandrashekar and Heather (1981). Plant host data was provided by U.S. Forest Service, western inventory section (Table 1). Uredospore dissemination is estimated based on disease outbreaks reported in New Zealand (van Kraayenoord *et al*., 1974).

Plant host data is generalized to the presence of susceptible species in each county in the States of California, Oregon and Washington. Species are included that support uredospore infection cycles (poplar) and aeciospores (larch) (CMI, 1975; Schall, 1992; Newcombe *et al*., 1994). Table 2 lists data accumulated on the number of counties containing Eurasian Poplar Leaf Rust susceptible hosts, *Larix lyalli, L. occidentalis, Populus balsamifera, P. tremuloides* and *P. Trichocarpa*.

Data analysis procedures include the operations of overlay, proximity, buffer, and measurements using either of the desktop GIS software packages, Maptitude or Atlas-GIS running under Windows 95. Network operations were performed only in the Maptitude software package. Spatial queries were derived from the elements of the pest risk assessment model. Examples of the spatial queries are listed in Table 3 along with the corresponding selection operations for each query performed in Atlas-GIS software.

3.0 RESULTS

Spatial analysis identified Washington as the State with the most counties (42) containing susceptible hosts to infection by all stages of the pathogen. Twenty-one counties were identified in the State of Oregon and eight counties were found in the State of California that have potential susceptible hosts. In addition, the hosts supporting aecial development (larch) were not found in the State of California (Table 2). Counties of immediate concern that have susceptible hosts to uredospore infection include: Multnomah in Oregon, and Clark, Cowitz and Skamania in Washington (Table 4). No adjacent counties were found that contained larch species. Distance measurements detected counties that were nearest infected counties in Washington, Ferry County had *P. tremuloides* and Klickitat County had *L. Occidentalis*. Possible truck routes for the movement of Eurasian Poplar Leaf Rust plant material from the infected counties were identified in all three states. These include the interstate highways of 10,15, 205, 215, 5, 8, and 805 (Table 4). Buffer zones of 20 and 100 mile size were created and covered multiple counties in all three states. These buffer zones could be used in the study of pathogen spread or management of the pathogen.

4.0 DISCUSSION

Schall (1992) used the pest risk assessment model to evaluate available information and determined the pest risk associated with the introduction, establishment and consequence of Eurasian Poplar Leaf Rust into nursery and forest resources of the United States. Using the framework of the pest risk model, Schall analyzed the available data for each element of the model and ranked each element with the level of risk and associated uncertainty. He concluded that Eurasian Poplar Leaf Rust is a high risk exotic disease with potential for establishment based on man assisted pathways, complexity of life cycle, and environmental requirements.

Geospatial analysis provides another tool for strengthening the risk analysis process, particularly in conjunction with pest risk assessment model. Based on preliminary studies, desktop GIS software packages, such as Maptitude and Atlas-GIS, are well suited for rapid analysis and both offer a wide range of geographic data. Import of database tables into both packages is relatively easy and data edits can be conducted either outside or within the software packages. GIS software is particularly good for analyzing the potential effect of environmental variables on colonization, spread and dissemination of diseases. Overlaying diverse sets of environmental data layers and performing complex queries can improve prediction and epidemiological analysis of specific trends and patterns.

During the GIS project, several issues arose that were related to the level of data resolution and scale needed for the pest risk assessment model. For example, the original data for plant hosts were collected at plot level but needed to generalized for the presence of susceptible hosts at the county level. This is often the case in GIS projects. Data is available at different scales or resolutions than whet is needed for the project. Additionally, the issue of data gaps surfaced during this study. Data on the susceptible hosts of the rust disease covered only the national forest areas, yet susceptible hosts may also be present in ornamental nurseries and native forested areas.

Desktop GIS software includes many of the operational functions found in the more sophisticated GIS software packages. These operational functions include: projection and spatial transformation utilities; spatial retrieval; classification and measurements; logical and visual overlaying capabilities; proximity and network functions; and map algebra. Some of the most sophisticated tools for spatial analysis such as 3-D modeling and contouring are not found in the versions of the two desktop GIS packages tested in this study. However, desktop GIS software packages meet many of the needs of the pest risk assessment process, with the added benefits of ease and rapid performance.

Continuing efforts focus on refinement and standardization of geospatial analysis procedures associated with the pest risk assessment model. Geospatial results continue to be evaluated based on past pest risk assessments and availability of new information. Future efforts include use of numerical probability estimates and development of new GIS applications for the pest risk assessment model.

5.0 REFERENCES

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Table 1. U.S. Map Data

Background Map Data	Eurasian Poplar Leaf Rust Data
State Boundaries	Plant Hosts by County
County Boundaries	Disease Incidence by County, 1992
Water Features	Temperature Limits for Uredospore Germination
Streets	
Roads and Highways	
Railroads	
Cities	
Landmarks	

Table 2. Number of counties containing susceptible plant hosts

Species	**Oregon**	**Washington**	**California**
Larix lyalli	0	0	0
Larix occidentalis	10	14	0
Populus balsamifera	0	0	0
Populus tremuloides	4	7	5
Poupulus trichocarpa	7	21	3

Table 3. Spatial Query Examples

Spatial Queries	**Steps**
Identify counties containing susceptible hosts, *P. trichocarpa* and *P. tremuloides*, surrounding counties reporting rust disease	Steps: Select-Layer-Rust Select-Geographic-Touching Edit-Attribute-Browse-View-Filter
Identify counties containing hosts able to support sexual stage of the disease adjacent to counties reporting disease	Steps: Select-Layer-Rust Select-Geographic-Touching
Determine distance of counties containing *P. tremuloides* and *P. occidentalis* from nearest counties reporting disease	Steps: View-Distance
Identify interstate highways near infected counties in the states of California, Oregon and Washington	Steps: Select-Layer-Rust Select-Geographic-Touching Edit-Attribute-Browse-View-Filter
Construct 20 mile and 100 mile Buffer Zones around counties reporting disease	Steps: Select-Layer-Rust Operate-Buffer-Zone

Table 4. Results of Spatial Query Examples

Spatial Queries	**Data Retrieved**
Counties containing susceptible plant hosts surrounding counties infected with Eurasian Poplar Leaf Rust	Oregon-Multnomah County Washington-Clark, Cowitz and Skamania Counties
Counties containing plant hosts able to support the sexual stage of the pathogen surrounding counties infected with Eurasian Poplar Leaf Rust	No counties selected
Distance of counties containing *P. tremuloides* and *L. occidentalis* from nearest infected county	*P. tremuloides* in Ferry County, Washington is 21.8 miles at 1:5803150 scale from Clark County, Washington *L. occidentalis* in Klickatat County, Washington is 34.6 miles at 1:5803150 scale from Clark County, Washington
Interstate highways near infected counties in the states of California, Oregon and Washington	Interstate highways 10, 15, 205, 215, 5, 8, 805 were selected
Quarantine buffer zones surrounding counties reporting Eurasian Poplar Leaf Rust	20 mile and 100 mile buffer zones covered multiple counties in the states of California, Oregon and Washington